RFMD™

UF MURI Kickoff

MURI Kickoff Agenda

- Introductions
- RFMD Background
- RFMD Technologies
- Reliability Processes and Technology Qualifications
- Reliability Issues and Examples
- Future Trends

Introductions

- **Dr. Michael Fresina**
  - Director, Device Engineering, Wafer Fabs
  - Responsible for new technology development, fab test engineering, characterization and reliability

- **Dr. Michael Antonell**
  - Senior Manager, WW FA, REL, AS
  - Responsible for failure analysis, corporate reliability lab and advanced analytical solutions
  - UF MURI liaison

RFMD at a Glance

Important Facts

- Global employees: 4,000+
- Founded in 1991
- ISO 9001 and ISO 14001 certified
- FY08 revenue: U.S. $957.6 million
- FY08 pro forma operating income: U.S. $13.5 million
- FY07 total assets: U.S. $2.121 billion
- NASDAQ: RFMD
- Website: www.rfmd.com

Mission

- To extend and leverage our leadership in RF components and compound semiconductor technologies into multiple industries.

End Markets

- Mobile handset and device
- Wireless data
- Wireless infrastructure
- Aerospace and defense
- Broadband and consumer
- General Purpose RF components

Global Reach — 4000+ Employees

RFMD™

Global Operations

Greensboro, NC: Molecular beam epitaxial (MBE), compound semi-conductor fabrication and test

Newton Aycliffe, UK: GaAs pHEMT fabrication facility

Beijing, China: Semiconductor assembly, internal module packaging, tape and reel

Broomfield, CO: Aerospace and Defense assembly and test

Brooksville, FL : Signal source component design; MCM manufacturing and test

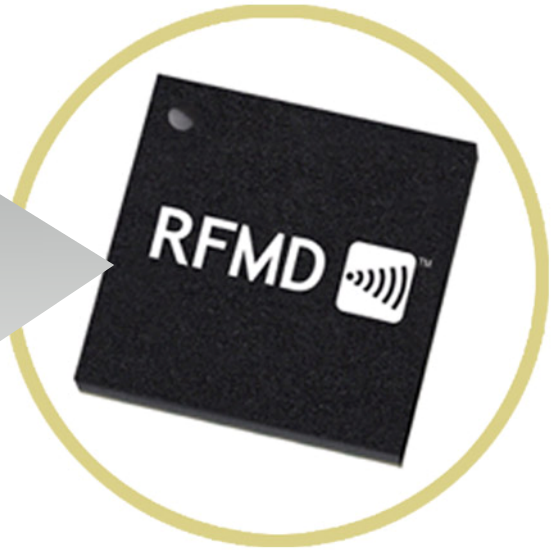
Nuremberg, Germany: CATV component design and manufacturing

Shanghai, China: Passive component manufacturing, ETS in-sourcing, integration, and board-level and subsystem assembly

The Optimal Fit

Through Optimum Technology Matching® (OTM), RFMD engineers match the appropriate technologies to each product according to the best possible combination of price and performance.

- MCM Integration
- AlGaAs HBT
- Gallium Nitride (GaN)
- PowerStar®
- CMOS
- SiGe
- GaAs pHEMT
- GaAs MESFET
- MicroShield™
- Silicon BJT
- GaAs BiFET
- InGaP HBT
- SAW Filters



RFMD Technology Portfolio

- **External Foundries**

SiGe | CMOS | GaAs MESFET | Silicon BJT

  - Foundry responsible for qualification including reliability.
  - RFMD is sourcing established process technologies.

- **Internal Technology**

AlGaAs HBT | InGaP HBT | GaAs pHEMT | Gallium Nitride (GaN) | GaAs BiFET | SAW Filters

  - RFMD technology development and qualification.

RFMD Internal Compound Semiconductor Technologies

- **AlGaAs HBT**
  - Initial process licensed & transferred from TRW
  - Be-doped base
  - 4th generation in production
  - Internal MBE epi supply
- **InGaP HBT**
  - C-doped base
  - 2nd generation in production
  - External MOCVD epi
- **GaAs pHEMT**
  - 2nd generation in production
  - Switch and PA applications
  - Internal MBE epi
- **GaAs BiFET**
  - 2nd generation in production
  - Switch and PA applications
  - Internal MBE and external MOCVD epi
- **SAW Filters**
  - 1st generation in production
  - LiTaO substrates, AlCu metal
- **GaN HEMT**
  - 1st generation in production
  - External MOCVD epi

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- **Reliability Issues and Examples**
- **Future Trends**







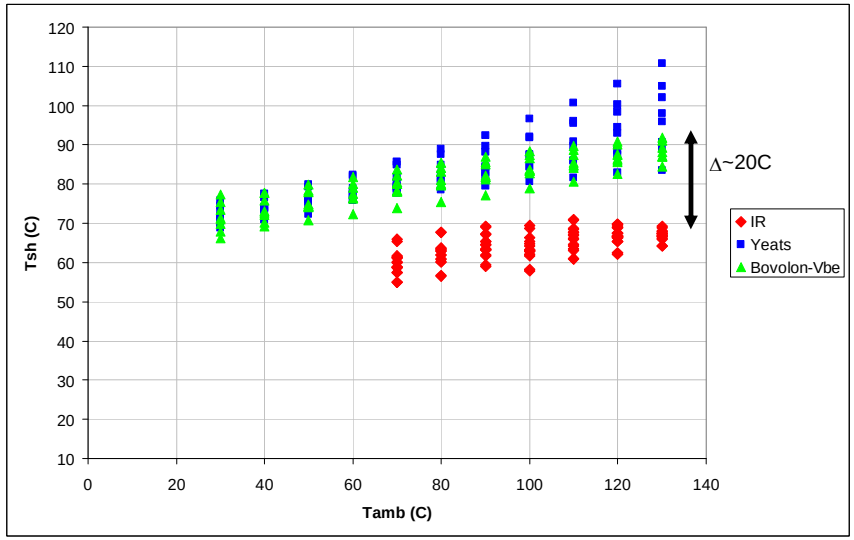

Reliability Testing for Technology Qualifications

- **Discrete device "3-temp" lifetest**
  - Usually 3+ temperatures
  - Typically multiple current densities (HBT) to determine SOA
- **Early in development process depending upon risk**
- **Std criteria is MTTF(125) > 1E6 hours (prefer LCL)**
- **Migrating towards FIT predictions**
  - Failures-in-time, failure rate for first N years (typ 7)
  - Considers predicted failure distribution at use condition
  - Scaled to typical application
- **Also various environmental tests (ESD, THB, HAST)**

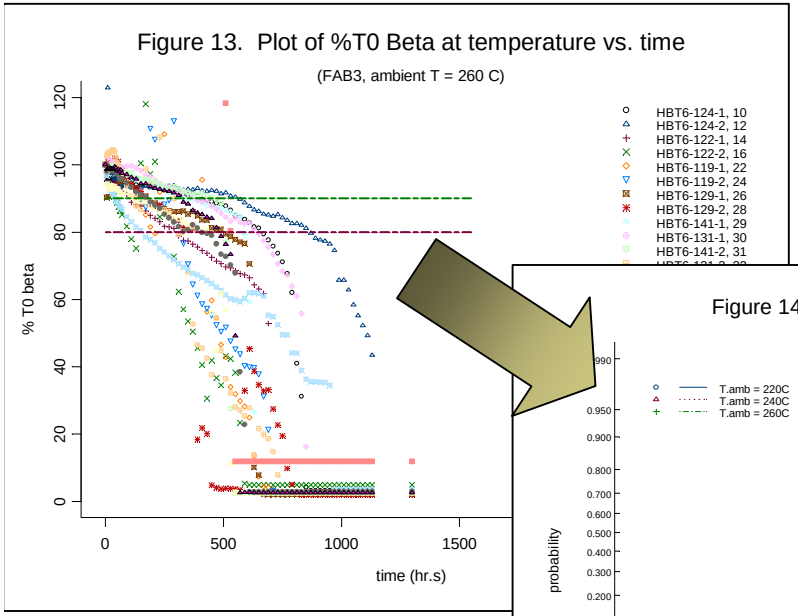
Life Test Procedures

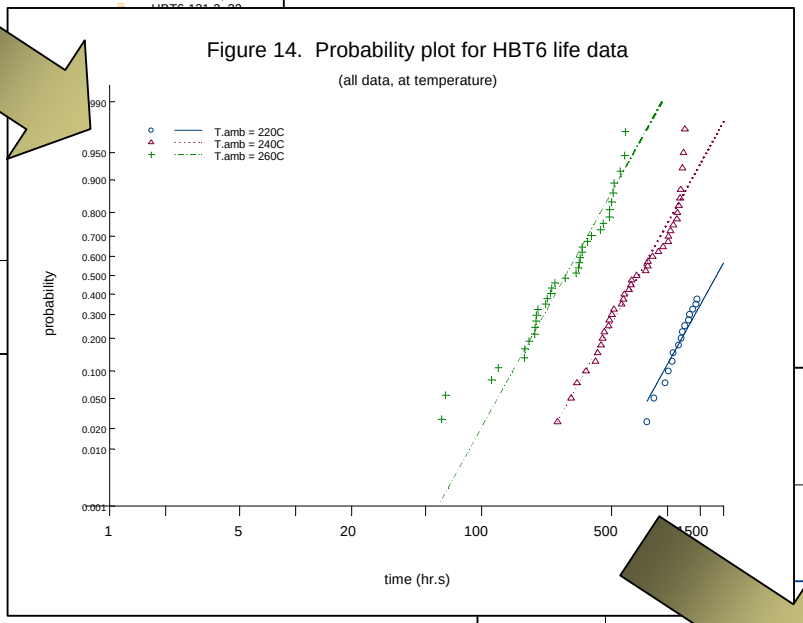
- **Discrete device**
- **Max bias conditions, or varied to extract SOA**
- **Ambient temps selected for max Tj typically < 300-320.**
- **Lower temps almost always run eventually to verify E_A**

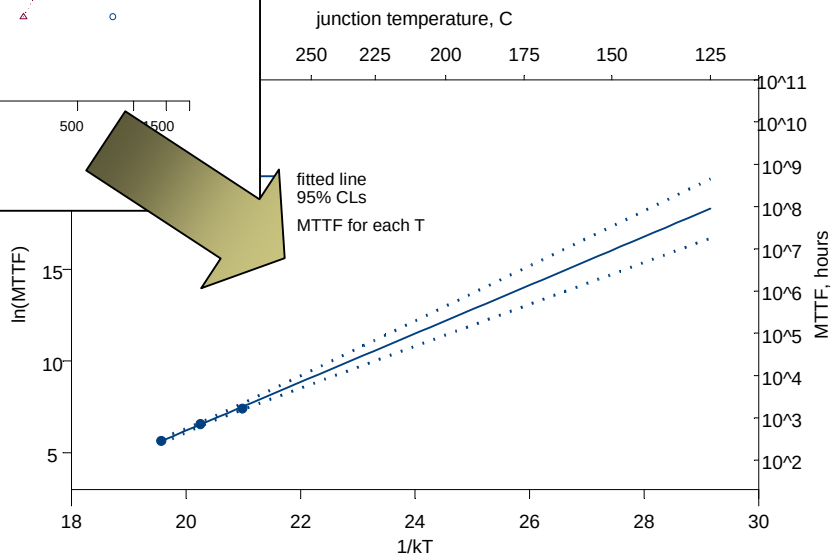
- **Self Heating**
  - IR
  - Electrical methods
    - Yeats, Bovolon
  - $T_{sh,IR} < T_{sh,Electrical}$
  - Use IR for conservative reliability estimates



Life Test Data Analysis



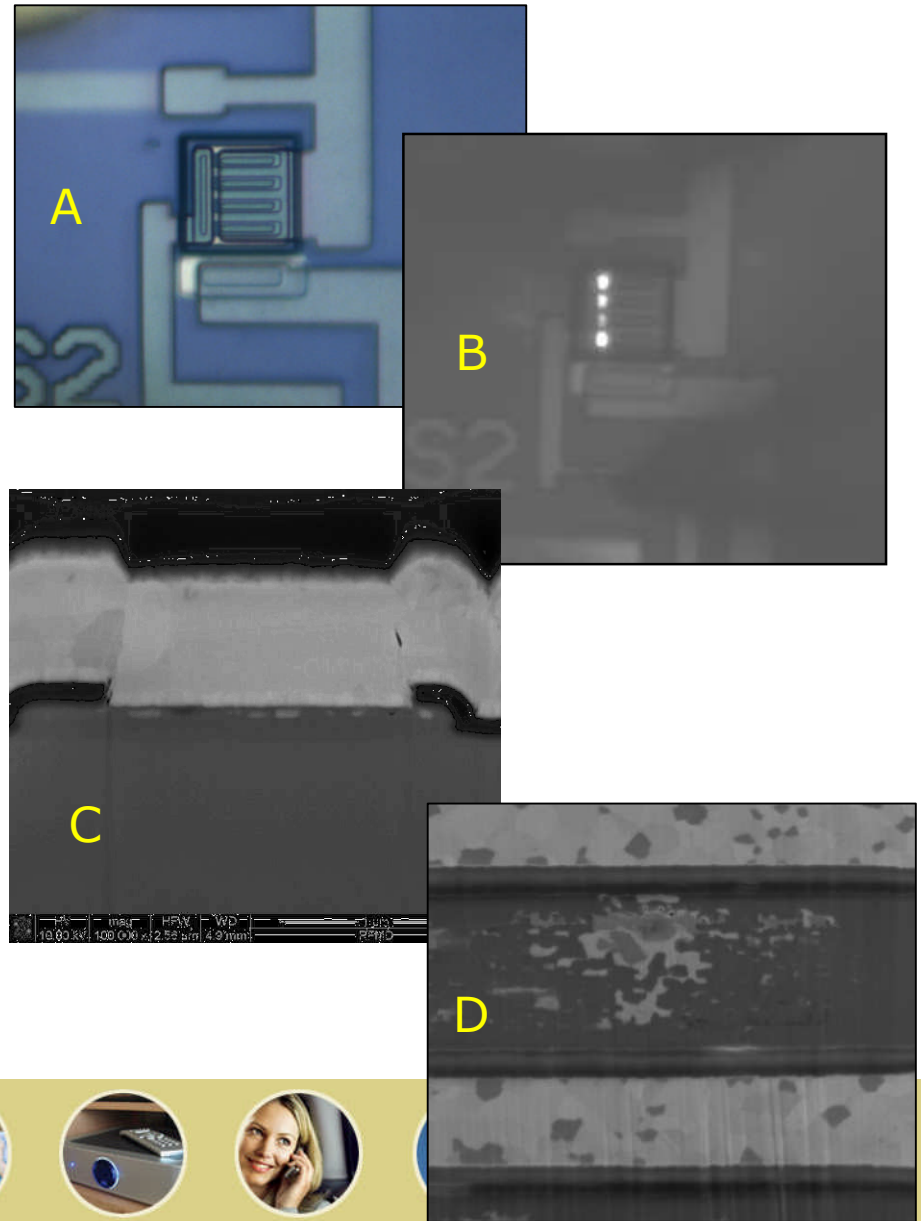




Typical Failure Analysis

- **Pre- & post electrical baseline**
- **Non-destructive**
  - Visual
  - PEM
  - SEM
  - High Res x-ray
- **Destructive**
  - FIB
  - “de-processing”
  - Laser isolation

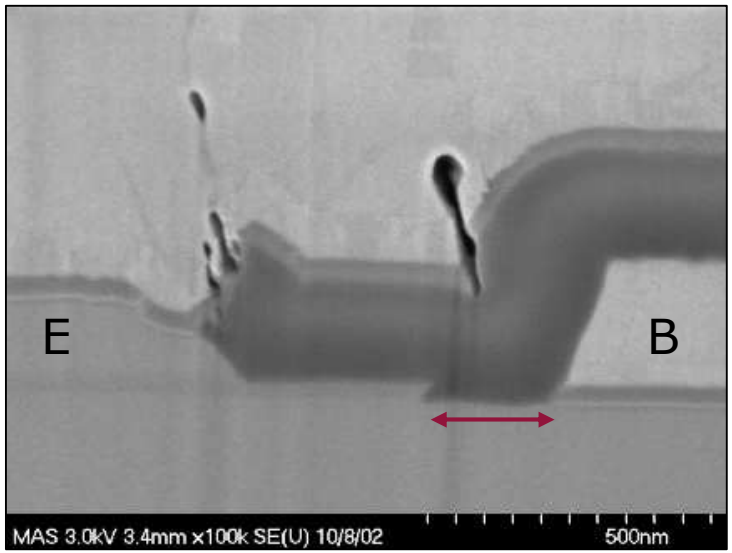
More important when we are not meeting reliability requirements!



Example: HBT Reliability Issues

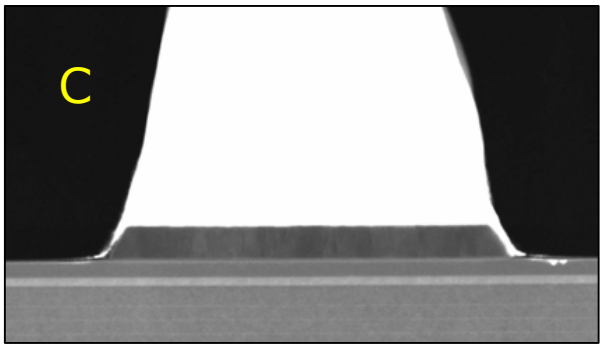
- **Failure modes generally assumed:**
  - Be-diffusion
  - REDG
  - Both very difficult to identify/verify

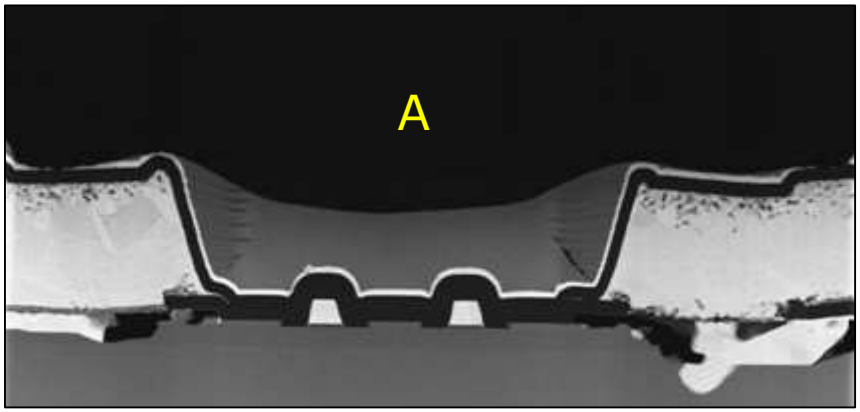
- **Excess unpassivated base surface increased surface recombination and REDG leading to early beta wearout.**

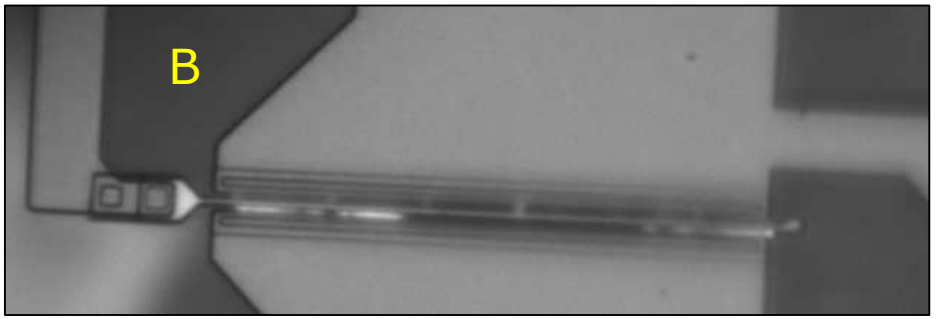


Example: FET Reliability

- **Ohmic degradation**
  - Changes to access resistance
- **Gate sinking**
  - Metal-semiconductor interaction
    - Gate leakage
    - Barrier height changes
  - Intermetallic mixing







Future Trends: Technology and Reliability

- **Technology**
  - More integrated processes (multiple active devices on same substrate)
  - Smaller devices
  - Higher density circuits
- **Reliability Testing**
  - Production screening (WLR?)
  - More V&I acceleration to compliment temp acceleration
  - Step stress test
- **Failure Analysis**
  - T_{sh} measurements
  - p-n junctions location, defects, and doping non-homogeneities
  - Chemical/physical analysis of intermetallics and interdiffusion products

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